POTASH TAILS PILE FIELD TEST COVERS

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ABSTRACT

A field test program was established to examine potential potash tails cover materials and investigate the requirements of such covers. Potash tails consist of soluble salts and a small percentage of insolubles. Precipitation falling on these tails dissolves the salt, creating a saturated liquid brine. Most of the brine generated is contained in ponds around the base of the pile, and periodically injected into deep underground formations. The use of covers to minimize brine generation is one method currently being examined as a decommissioning option. A preliminary three year laboratory program and review of potash cover experience was used as the basis for designing the field cover program. Two full scale 20m X 20m test covers have been constructed on an abandoned potash tails pile. One of the covers was constructed from glacial till overlying a coarse boulder capillary barrier. The second was constructed from polymerized bentonite and sand. These covers are currently being monitored to evaluate their performance.
Les dépôts de résidus à potasse sont constitués surtout de sel (NaCl) et d'un petit pourcentage de matières insolubles. Les précipitations en dissolvant le sel, produisent une saumure saturée. Cette saumure s'écoule vers le bas et vers la périphérie des dépôts. La grande partie de cette saumure est contenue. Cependant, des questions se sont posées concernant les effets à long terme de cette pratique de gestion des résidus, surtout dans un contexte de fermeture de mines de potasse. Pour répondre à certaines de ces questions et pour examiner les diverses alternatives, l'industrie de la potasse a pris l'initiative de développer la recherche visant à évaluer divers matériaux et revêtements d'entassement, comme option lors de la fermeture de sites miniers. Cette communication résume la recherche portant sur ces revêtements et décrit des essais sur le terrain du rendement de ces revêtements.

En 1987, un programme de recherche fut instauré pour évaluer divers types de matériaux pouvant être utilisés comme revêtements des entassements de potasse. En raison de la présence d'une grande quantité de matières insolubles, produites par les travaux d'exploitation minière, ces recherches ont été concentrées vers l'inclusion de ces matières au sein de mélanges particuliers tels que: la moraine glaciaire, la kaolinite, le ciment, les cendres volantes ainsi que les sols conventionnels. Les mélanges furent soumis à divers essais, incluant la perméabilité, la flexibilité et la force tensile. Sans être extraordinaires, les résultats furent suffisamment encourageants pour recommander la construction de certains types de revêtement sur le terrain.

En 1989 et 1990, une série de revêtements furent installés sur le sommet d'un entassement de potasse à l'est de Saskatoon. Le premier revêtement, de 20 m par 20 m, comprenait 0.5 m de roches et de blocs. Ces matériaux ont été placés sous une couche de moraine de 1 m d'épaisseur afin de séparer les résidus salins. Une couche granulaire grossière servait également de barrière capillaire pour empêcher le mouvement vers le haut du sel en solution. Le deuxième revêtement, de même dimension, comprenait de la bentonite polymérisée, pour contrer les attaques chimiques de la saumure, et du sable fin propre. Les deux revêtements étaient recouverts d'une couche granulaire protectrice. Des lysimètres y furent placés pour mesurer l'infiltration. Une troisième couverture, plus petite, se composait d'un matériau synthétique. Le rendement de ces trois revêtements est présentement à l'étude.
INTRODUCTION

This paper describes the results of recent research into the design and construction of covers for potash tails piles. This work began with a three year laboratory testing program and investigation of potash tails covers in other countries. The laboratory program was primarily directed at evaluating the use of potash thickener slimes as a potential cover material. In this study, the impact of addition of various soil liner materials to slimes was examined. The first phase of this research exposed many of the difficulties associated with covering potash tails piles and provided information on which a field test cover program could be based. The second phase of this research was followed by the design, construction and instrumentation of two field test covers. These test covers were placed on an abandoned potash tails pile located near Saskatoon, Saskatchewan. The first test cover constructed was composed of glacial till overlaying a layer of boulders. The second cover was constructed using polymerized bentonite and sand.

BACKGROUND

Potash tails piles consist primarily of soluble waste salt (NaCl) and a small percentage of insolubles. Precipitation falling on the tails piles dissolves the salt and creates a saturated brine. This brine flows downward and outward from the tails piles. While most of the brine generated is contained, some questions have arisen over the long term implications of this waste management practice, especially as it related to decommissioning of potash mines. In an attempt to minimize the environmental impact associated with shutting down mines, a number of decommissioning options have been considered. These options generally fall into two categories, those which involve continued above ground disposal and those which involve underground disposal of tails. One of the primary above ground options being considered involves the use of covers.

Figure 1 conceptually illustrates how a cover would be used to direct precipitation off the tails pile and reduce the dissolution of the soluble tails. The clean runoff water would be collected and directed off the site. Any brine generated by infiltration would be collected separately and injected underground.

Figure 1: Conceptual View of the Operation of A Potash Tails Pile Cover.
PRELIMINARY INVESTIGATION

A three year laboratory testing program was initiated in 1987 to evaluate various potential cover materials for potash tails piles. This program examined a wide variety of potential liners. A significant quantity of insolubles are generated as a result of the mining operations. The use of these materials was first examined in a study conducted by Hart (1985). As a result of this work, most of the laboratory research concentrated on the use of various soil admixtures in combination with thickener slimes. These soil admixtures included glacial till, kaolinite, cement, fly ash and other traditional soils.

An emphasis was placed in this research on the creation of a material which could be slurried out over the tails to seal the surface. Test liner material specimens were prepared by mixing various percentages of the soil admixtures to saturated slimes slurry. These slurried mixtures were poured in thin lifts into glass jars. Each lift was allowed to dry before additional material was added. These materials were subjected to a variety of standard laboratory tests including triaxial and fixed wall permeability, flexibility and strength. The results of this laboratory program found few materials which could perform in a salt environment.

There are few example of covers being used to seal the surface of potash tails piles. However, one cover has been installed on the abandoned Hansa potash tails pile near the outskirts of Hannover, Germany. This old Kai und Salz pile was begun in 1915 and abandoned in the early 1960's. It presently contains approximately 2 million tonnes of salt. In 1977, this tails pile and the property it is located on was purchased by a former employee, who set up a company to handle the disposal of construction materials. As these materials are now brought to the site, they are used to construct the cover. The basic design of this cover involves placing 2 m of coarse rubble over the surface of the tails to form a capillarity barrier. The coarse rubble is covered with less coarse sands and gravels. This capillary barrier is then covered with low permeability till and clay.

DESIGN CONSIDERATIONS

The laboratory testing program and the review of potash cover experience demonstrated the many difficulties associated with covering potash tails piles. The primary difficulty was to design a cover which could perform in contact with salt. This and the other problems identified can be illustrated by examining the factors which modify or alter the structure of soil liners (Figure 2). The performance of covers are usually measured in terms of permeability, flexibility and strength. These factors are controlled by the soil structure and can be altered during the life of the cover. The initial structure of soil can be altered with time by physical, chemical and biological processes. The physical processes include consolidation, wet/dry cycles, freeze/thaw cycles, and erosion. The chemical processes include dissolution, osmotic consolidation, mineralogical transformations, sorption and precipitation. Biologically, soil structure can be altered by various bacterial actions occurring in the soil. The effect of these processes may be to produce a final long-term soil structure which may result in failure of the cover. Since covers are usually intended to perform for extended periods of time, a primary requirement of a cover design is to minimize the negative impact of these processes on long-term performance.

In the case of potash tails covers, the primary processes which have to be accounted for are physical and chemical in nature. The physical processes of most concern are freeze/thaw cycles, wet/dry cycles and settlement. In order to
minimize the effects of frost, many covers are made sufficiently thick to prevent frost from reaching the lower levels of the cover. In the case of a potash tails pile 1 km in size, this would require 9 million m of soil for a 3 m thick cover. The use of this quantity of soil would likely result in a significant alternation of the local environment itself and therefore be unacceptable. Thus, one basic assumption of this design was that potash tails covers would be frozen periodically through their full depth.

The yearly precipitation in the potash mining areas varies from 350 to 450 mm. Thus, the surface of a potash tails pile cover would be periodically wet. The depth of wetting during rainfall would depend on the characteristics of the cover material as well as the slope of the cover and duration of precipitation event.

Settlement of the tails piles is another potential problem for potash tails covers. Some settlement within the tails pile itself is anticipated due to consolidation. Additional subsurface settlement due to closure of underground mined out areas is also anticipated; however, these settlements are spread over a large area and are not expected to adversely affect performance of potash tails covers. Of greater concern is settlement caused by dissolution of the tails due to precipitation infiltrating through flaws in the cover. This dissolution would undermine the cover resulting in a foundation failure which could lead to rapid failure of the entire cover.

Figure 2: Factors controlling the final structure of compacted soil cover materials
Osmotic consolidation is the primary chemical process which could potentially adversely affect the performance of potash tails covers. Compacted earth covers placed in contact with the salt would provide a conduit for the upward migration of salt. The upward movement of salt through clay and till soils was observed in laboratory tests conducted by Haug (1988), during research into potential cover materials for potash tails piles. This upward moisture movement could transport salt to the surface. The presence of salt in the lightly consolidated clay could osmotically consolidate the soil cover resulting in the development of a more permeable secondary structure.

DESIGN OF FIELD TEST COVERS

Two test covers were constructed on an abandoned potash tails pile, one from glacial till overlying a boulder layer and the other from polymerized bentonite and sand.

A plan view of the till test cover and the adjacent sand-bentonite test cover is shown in Figure 3. This figure also shows the X-Y coordinate system and tails pile surface elevations (geodetic) on a 10 m grid. The covers were both laid out parallel to the direction of maximum tails surface slope. This direction was at an angle of 12° 57' to grid north. Two dark squares are shown around the till cover. The inner square shows the location of the full depth till cover. The outer square shows the location of the contact between the side slope of the cover and the tails surface. The dashed zone inside the tail cover areas denotes the location of the lysimeter.

A profile section (A-A, in Figure 4) is shown in Figure 4. The vertical scale in this figure is exaggerated 2.5 times that of the horizontal. This figure shows the main zones within the cover and the characteristics of the lysimeter.

Till Test Cover

The preliminary assessment of material characteristics were used in the design of this test cover. The standard Proctor optimum water content and maximum dry density was found to be 9.5 % and 2080 kg/m³, respectively (Figure 5). This design envisaged the construction of a till cover overlying a granular capillary barrier. The required characteristics of this layer was that it be relatively coarse, possess little fines, be uniformly graded, and have an overall thickness of 0.5 m. The design also called for the construction of a 1 m compacted till cap to overlie the granular barrier. Movement of fines from the till into the capillary barrier was controlled with a well graded sandy filtering material. The laboratory tests indicated that for the till a permeability of approximately $1 \times 10^{-6}$ cm/s could be achieved with a water content and density near standard Proctor values (Figure 6). Infiltration studies suggested that precipitation would not penetrate the full depth of the cover under initial placement conditions. Cover protection was also provided for the cover to minimize desiccation during the summer months.
Figure 3: A plan view of the till test cover and adjacent sand-bentonite cover.
Figure 4: A profile section (A-A) of the till cover

Figure 5: Standard and modified Proctor curves.

Figure 6: Permeability versus time plot for till cover material.
Sand-bentonite Test Cover

The sand-bentonite cover designed for the potash tails pile consisted of 8% polymerized Enviroseal bentonite mixed with clean sand. The standard Proctor curves for 6 and 8% bentonite with sand are presented in Figure 7. The standard Proctor optimum water content and maximum dry density of 8% bentonite with sand mixture was found to be 11% and 1.93 kg/m³, respectively. The permeability versus time curve of 6% bentonite with sand mixture is presented in Figure 8. The permeability of the mixture was found to be 4.5 x 10⁻⁶ cm/s at 40,227 minutes. The bentonite was to be worked into the sand with a mixer capable of providing adequate mixing and equipped to enable the uniform addition of water to increase the water content up to the desired molding water content. This molding water content was approximately 11%. The maximum specified dry density was approximately 100% of Standard Proctor or near 1.93 Mg/m³. The liner was also to be constructed in two 0.125 m thick lifts and covered with a protective granular layer.

Figure 7: Standard Proctor curves for 6 and 8% bentonite sand mixtures.

Figure 8: Permeability versus time plot for 6% bentonite and sand.
CONSTRUCTION OF THE TEST COVER

The installation of the lysimeter was the first step in the construction of the test covers. Since infiltration through the cover was expected to be low, a large 6 m x 6 m lysimeter was selected. A number of methods were examined to excavate the salt tails for this lysimeter. Chain saws were used initially to cut 0.3 m square blocks. Although this technique had worked satisfactorily at other active potash tails facilities, little success was achieved with this method at this site. A standard hydraulic excavator (backhoe) was later employed to excavate the tails; however, this machine was very slow and eventually broke down trying to dislodge the tails. Eventually, a larger hydraulic excavator with a telescoping boom was used successfully, if somewhat slowly, to excavate the lysimeter area.

The lysimeter collection system was centred on a large plastic water tank cut in half. This half tank was filled and surrounded with compacted, screened gravel. A high density polyethylene (HDPE) geomembrane was placed over the surface of the sand and configured to collect water infiltrating the cover over the 6 m x 6 m area, funnelling it into the tank. A drain at the bottom of the tank was connected to a plastic polyvinyl chloride (PVC) pipe sloped to transport the water to the monitoring trench.

Till Test Cover

Boulders up to 0.3 m in diameter were placed over the sand cover lysimeter and adjacent salt tails to the outer limits of the cover. The boulders were hauled by truck to the tails pile and spread with a hydraulic loader. Boulders larger than 0.3 m in maximum dimension were rejected. Smaller rocks were placed between the boulders by hand. The boulder layer was covered with 165 m of screened fine gravel and coarse sand and compacted to form a granular layer of approximately 0.5 m in thickness. The surface of this zone was covered with approximately 37 m of uniformly graded pit run gravel to provide a level surface that acted as a barrier to the downward movement of fines from the till cover material.

The till was placed over the granular capillary barrier in five 0.2 m thick lifts. The till was moistened during construction with water sprayed by hand. The till was compacted with a deep foot self-propelled pad roller to provide full lift compaction. The surface of the cover was graded to provide a smooth surface. This surface was covered with a 0.25 m thick granular protective cover. The water content and dry density of each lift was measured with the nuclear density instrument, and referenced in X-Y-Z coordinates. The average water content for lifts no. 1, 2, 3, 4, and 5 were 11.3, 9.9, 9.6, 10.3 and 10.2 respectively. These values agree closely with the standard Proctor optimum value of 9.5 %.

The average density for lifts 1, 2, 3, 4, and 5 were 83, 88, 93, 94, and 95 % of standard Proctor. The relatively low values compared to standard Proctor measurements were attributed to difficulties in obtaining density over top of the coarse boulder layer. As the thickness of the granular layer increased, the densities improved significantly. The surface of the till was covered with a 0.05 m layer of screened gravel. This layer was intended to minimize surface erosion and desiccation. The cover was wetted periodically during the summer of 1990 in order to maintain its condition prior to freeze-up and to aid in desiccation prevention.

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Sand-Bentonite Test Cover

20 tonnes of Enviroseal Bentonite was transported by truck from Wyoming to the site where it was unloaded. Each pallet of bentonite was wrapped in plastic to protect it from the environment. The entire load was also covered with tarps to ensure that it arrived at the site in good condition. Clean sand was hauled to the site and spread over the lysimeter and adjacent salt tails to provide a layer 0.25 m thick.

A string grid 1.4 m X 1.4 m was placed over the cover area to provide a guide for the application of bentonite. A 45 kg bag of bentonite was placed in each square of the grid. The bentonite bags were broken open and spread using rakes and shovels. A Bomag pulvi-mixer then dry mixed the bentonite and sand. Two passes were made in each direction to thoroughly mix the sand and bentonite. The pulvi-mixer then wet mixed two passes in each direction. The depth of mixing had to be carefully controlled to ensure that the salt tails were not mixed with the sand and bentonite. This was accomplished by conducting a series of trial passes at different instrument depth settings.

A smooth drum roller was used to compact the sand-bentonite mixture. This technique worked well at this site, however, vibration during compaction caused patches of the cover surface to peel off and stick on the roller. Thus, most of the sand-bentonite cover was compacted with no vibration. A 0.05 m thick granular protective layer was spread over the surface of the sand-bentonite cover. This layer was identical to that used for the till cover. The average water content of the sand-bentonite cover was determined to be near 7.5 % and the average dry densities was measured to be near 103 % of standard Proctor values. While the water content values may appear somewhat below standard Proctor optimums, the impact for sand-bentonite mixtures is almost negligible.

SUMMARY

The design and installation of these test covers has provided a valuable insight into many technical and practical considerations which must be addressed for the successful implementation of such project.

In the case of potash tails covers, some specific conclusions can be drawn. The difficulty in excavating these abandoned tails suggests that any substantial grading required to shape the tails prior to decommissioning will be difficult. Assuming that the capillary barrier approach is successful, problems are also likely to be encountered obtaining a sufficient quantity of boulders. Some further investigation may be required to examine the performance of gravel and sand capillary barriers.

Almost immediately after the construction of this cover problems developed during a major intense precipitation event. The "clean" water running off the surface of the till cover dissolved deep holes in the salt tails on the downslope edge of the cover. This problem was most severe near the lysimeter monitoring trench, which partially collapsed, permitting some till cover material to cave in. Because of this incidence, plans have been designed to collect the cover runoff and direct it downslope over the tails away from the test site.
REFERENCES
